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SYMPOSIUM: NEW APPROACHES TO SHOULDER SURGERY

Surgical Treatment of Winged Scapula

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Abstract Injuries to the long thoracic and spinal accessory nerves present challenges in diagnosis and treatment. Palsies of the serratus anterior and trapezius muscles lead to destabilization of the scapula with medial and lateral scapular winging, respectively. Although nonoperative treatment is successful in some patients, failures have led to the evolution of surgical techniques involving various combinations of fascial graft and/or transfer of adjacent muscles. Our preferred method of reconstruction for serratus anterior palsy is a two-incision, split pectoralis major transfer without fascial graft. For trapezius palsy, we prefer a modified version of the Eden-Lange procedure. At a minimum followup of 16 months (mean, 47 months), six patients who underwent the Eden-Lange procedure showed improvement in mean American Shoulder and Elbow Surgeons Shoulder scores (33.3–64.6), forward elevation (141.7–151.0), and visual analog scale (7.0–2.3). At a minimum followup of 16 months (mean, 44 months), 10 patients (11 shoulders) who underwent split pectoralis transfer also improved American Shoulder and Elbow Surgeons Shoulder scores (53.3–63.8), forward elevation (158.2–164.5), and visual analog scale (5.0–2.9). We encountered two complications, both superficial wound infections. These tendon transfers were effective for treating scapular winging in patients who did not respond to nonoperative treatment.

Level of Evidence: Level IV, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

Each author certifies that he or she has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.
Each author certifies that his or her institution has approved the reporting of this case report, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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Introduction

Winging of the scapula was first described over 250 years ago [43]. It can cause discomfort, decreased shoulder strength and range of motion, and create cosmetic deformity. The trapezius and serratus anterior muscles are integral to proper shoulder function, because they are the only muscles able to produce upward rotation and elevation of the scapula [17]. Scapular winging also presents a diagnostic challenge as evidenced by the fact that many of these patients are initially misdiagnosed [2, 3]. The two main causes of scapular winging are injuries to the spinal accessory and long thoracic nerves.

Spinal accessory nerve dysfunction causes scapular winging as a result of weakness of the trapezius muscle. Codman first described the importance of the trapezius in scapulothoracic motion when he coined the term "scapulohumeral rhythm" in 1934 [6]. Surgical treatment of trapezius palsy has evolved from static procedures such as scapulothoracic arthrodesis to the current treatment of transferring the rhomboids major and minor and the levator scapulae, the Eden-Lange procedure. Scapular winging from long thoracic nerve injury occurs because of serratus anterior palsy. Velpeau first described isolated serratus anterior palsy in 1837 [39], and today it is recognized as the most common cause of scapular winging [7]. In the past, various shoulder girdle muscles have been transferred in concert with soft tissue grafts for serratus anterior palsy. We currently prefer split pectoralis major transfer without use of soft tissue augmentation.

We describe our techniques for performing a modified Eden-Lange procedure and split pectoralis major transfer. We then asked whether these two procedures effectively treated winging and restored function. We also sought to further characterize the common causes of these palsies, pitfalls in obtaining the proper diagnosis, and possible surgical complications.

Materials and Methods

We retrospectively reviewed the records of 16 patients who had either a split pectoralis major transfers or Eden-Lange procedure from 2000 to 2006. We searched hospital records from 2000 to 2006 for the Current Procedural Terminology codes for muscle transfer, any type, shoulder or upper arm, single (23395) or multiple (23397). We then included only patients who had a split pectoralis major transfer or Eden-Lange procedure. All potentially eligible patients were enrolled. We identified 16 patients, 10 of whom had 11 split pectoralis major transfers and six of whom had Eden-Lange procedures. All patients had unsuccessful nonoperative treatment consisting of a physical therapy program. Scapular winging was present on physical examination of all patients in both groups. We performed a retrospective chart review to determine cause, age at time of surgery, time between injury and surgery, and prior diagnoses and treatments. Institutional Review Board approval was obtained and each patient provided informed consent.

Preoperatively, range of motion of the affected shoulder (forward elevation) was measured by the operating surgeon (LUB, WNL). We recorded visual analog scores of pain and American Shoulder and Elbow Surgeons Shoulder (ASES) evaluation scores [19]. Seven patients did not complete the preoperative ASES evaluation.

We performed 11 split pectoralis major transfers in 10 patients. One patient had bilateral serratus anterior palsy and had surgery on both sides. Eight of 10 were women. Two patients had concomitant trapezius palsy and one underwent combined split pectoralis transfer and a modified Eden-Lange procedure. The average age at the time of surgery was 33.6 years (range, 18–48 years). The patients had lived with serratus anterior palsy for an average of 6 years before surgery (range, 2–20 years). Two cases were idiopathic. Six cases were caused by various trauma, including motor vehicle accident, skiing, work-related injury, and football. One case occurred after multiple shoulder instability surgeries. One patient had serratus anterior weakness as a result of a form of fascioscapulohumeral muscular dystrophy (Table 1). Seven of the 10 patients were originally diagnosed with something other than serratus anterior palsy. Two patients were diagnosed with labral abnormalities and another with impingement; all three had unsuccessful arthroscopic procedures performed elsewhere before transfer. Another patient was diagnosed with thoracic outlet syndrome and underwent first rib resection. Cervical radiculopathy was diagnosed in one patient and was treated with anterior cervical discectomy and fusion. A patient with diabetes was diagnosed with adhesive capsulitis. Pectoralis rupture and Poland's syndrome were considered in another case. All 10 patients had electromyograms that demonstrated long thoracic nerve palsy before surgery. One patient had two negative

Table 1. Split pectoralis major patient demographics

Age (years)	Gender	Time to surgery (years)	Followup (months)	Mechanism	Preoperative ASES	Preoperative forward elevation	Postoperative ASES	Postoperative forward elevation
38	F	6	79.0	Instability surgery	—	170	45.0	170
33	F	12	65.5	Skiing/rib resection	85.0	180	—	180
41	F	2	44.5	Car accident	21.7	90	—	90
47	F	4	44.3	Idiopathic	63.3	180	80.0	180
33	F	13	31.9	Idiopathic	56.7	180	—	180
48	F	3	87.0	Ski injury	55.0	180	100.0	180
21	M	20	26.1	Scapuloperoneal dystrophy	36.7	60	78.3	110
23	F	2	25.5	Daycare	—	180	63.3	180
24	F	2	16.4	Daycare	—	180	25.0	180
44	F	2	43.9	Car accident	55.0	170	55.0	180
18	M	2	25.2	Football	—	170	—	180

ASES = American Shoulder and Elbow Surgeons Shoulder; F = female; M = male.

Table 2. Eden-Lange patient demographic information

Age (years)	Gender	Time to surgery (years)	Followup (months)	Mechanism	Preoperative ASES	Preoperative forward elevation	Postoperative ASES	Postoperative forward elevation
42	M	3	77.4	Posterior fossa decompression	35.0	120	75.0	170
41	M	13	36.8	Waterskiing	31.7	160	—	165
37	F	2	10.5	Cervical node biopsy	—	180	70.0	—
45	F	3	88.6	Car accident	—	130	45.0	150
54	F	4	41.3	Radical neck dissection	—	90	68.3	90
18	M	2	25.2	Football	—	170	—	180

ASES = American Shoulder and Elbow Surgeons Shoulder; M = male; F = female.

electromyograms in the past that did not comment specifically on the long thoracic nerve. For all patients in this study, MRI was not generally performed unless the patient had a comorbid condition (ie, instability, rotator cuff tear). Four patients in the split pectoralis transfer group did not complete preoperative ASES questionnaires, and an additional four did not complete postoperative questionnaires; they could not be located and were considered lost to followup. All patients had documented pre- and postoperative range of motion examination, of which the minimum followup was 16 months (mean, 44 months; range, 16–79 months).

Six patients underwent a modified Eden-Lange procedure for trapezius palsy during the specified period. There were three men and three women in this cohort. The average age at surgery was 39.5 years (range, 18–54 years), and the average time between injury and surgery was 5 years (range, 2–13 years). Three cases were the result of iatrogenic injury; one during cervical lymph node biopsy, another during radical neck dissection for thyroid cancer, and another from posterior cranial fossa decompression for Arnold-Chiari malformation. The other three were the result of trauma: waterskiing, motor vehicle accident, and football (Table 2). One patient was originally diagnosed with impingement syndrome. Two patients had concomitant long thoracic nerve palsy. Another patient had concomitant suprascapular nerve palsy, instability, and subscapularis tear and that patient underwent concurrent pectoralis major transfer. One patient had undergone unsuccessful sural nerve graft. All the patients had preoperative electromyograms demonstrating spinal accessory nerve palsy. The spinal accessory nerve was not originally tested in one of the patients with combined serratus and trapezius palsy, but was positive on repeat electromyogram.

Four patients in the Eden-Lange group had not completed ASES questionnaires preoperatively, and two did not complete postoperative questionnaires; because they could not be located they were considered lost to followup. All patients had documented preoperative range of motion examination, and all but one had postoperative range of motion. That patient was recovering from subsequent irrigation and débridement (further described in Results). The minimum followup was 16.3 months (mean, 47 months; range, 16–89 months).

Our preferred method of treatment for serratus anterior and trapezius palsy are split pectoralis major transfer and modified Eden-Lange procedure, respectively. When performing split pectoralis major transfer, we used regional anesthesia in conjunction with general endotracheal anesthesia. The patient was then placed in the full lateral decubitus position and held securely with a bean bag. We used a two-incision technique. We made the first incision 5 cm in length along the axillary skin crease (Fig. 1). The arm was abducted to accentuate the interval between the sternal and clavicle heads of the pectoralis major and its insertion on the humerus identified. The sternal head was sharply dissected from its humeral insertion to the axilla, staying medial against the chest wall to avoid the neurovascular structures that lie laterally (Fig. 2). Color-coated

Fig. 1 A 45-year-old right hand-dominant woman had a 2-year history of scapular winging; electromyography documented serratus anterior palsy. The patient is in the lateral decubitus position. The head is to the right-hand side and the feet are left. The anterior axillary deltopectoral incision is drawn out.

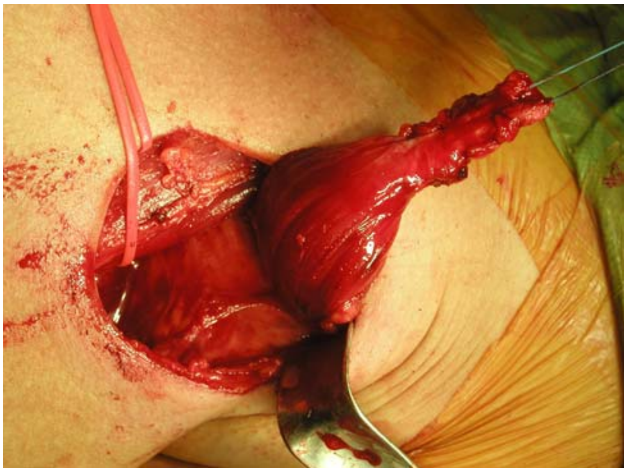

Fig. 2 The sternal head of the pectoralis major has been released from its humeral insertion. The arm is to the left-hand side and the torso is right. Vessiloop has been placed around the clavicular head superior to the sternal head.

sutures were placed in the tendon to maintain proper orientation on shuttling through the second incision. We made the second incision 6 cm in length over the inferior angle of the scapula. The inferomedial portion of the scapula was exposed by subperiosteal dissection of the infraspinatus, subscapularis, and serratus anterior. A long clamp was then passed from the anterior wound to the posterior wound to retrieve the sutures placed in the pectoralis major tendon (Fig. 3). To avoid the need for a soft tissue extension or interposition, we modified the suturing technique from the original description [7]. Earlier techniques involved making a hole in the scapula and passing the tendon through the hole and securing it to itself. On some occasions, this led to insufficient tendon length and compromised transfers and results. We now prefer to make a series of drill holes in the scapula and pass mattress sutures from the dorsal side through the transferred tendon and back up through the tendon and through the second drill hole. A series of these mattress sutures were passed and then sequentially tied with the tendon pulled to appropriate position and the scapula held in a reduced position (Figs. 4, 5). Routine closure was performed; the wounds healed with a cosmetically appealing scar. The advantages of this technique are there is a broader surface area of tendon apposed to the ventral scapula and there is no need for tendon graft interposition or extensions.

Fig. 3 A long clamp has been placed from the anterior wound along the ventral surface of the scapula. A second clamp will be attached to the first clamp and then brought out the anterior wound. The sutures from the pectoralis major sternal tendon will then be placed into the second clamp, which is brought back out the posterior wound.

For the first 6 weeks postoperatively, the patients remained in a sling and performed gentle pendulum and isometric exercises. Progressive strengthening with both active and passive range of motion of the shoulder girdle was started thereafter. At 12 weeks, we permitted return to noncontact athletic activities. We instructed patients to abstain from heavy lifting of more than 20 pounds for 6 months.

The modified Eden-Lange procedure was performed under general anesthesia with the patient in the full lateral decubitus position with the head of the bed elevated 15°. A

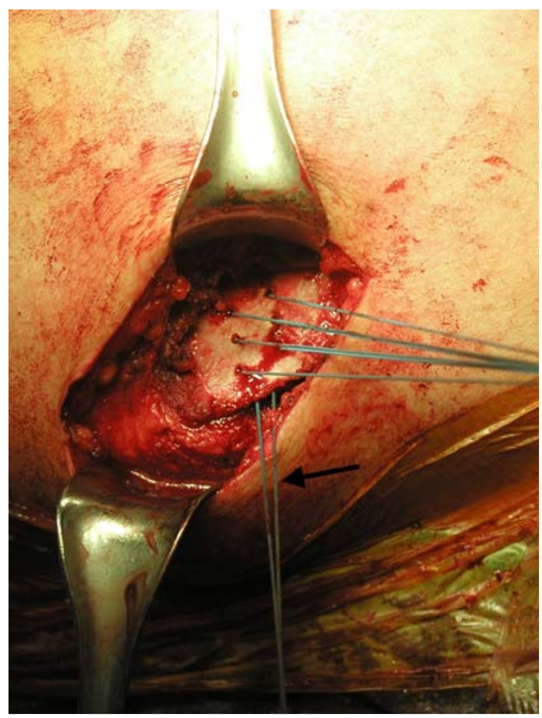

Fig. 4 A series of drill holes are made in the scapula taking care to protect the thoracic cavity below. Sutures are then placed from the dorsal surface through the transferred tendon back up the tendon in a mattress fashion and then out through the matching drill hole. The tendon-gripping sutures are pulled to maximal tension (arrows) before the definitive sutures are placed in the scapula.

Fig. 5 The mattress sutures are then sequentially tied along the dorsal surface affecting a secure repair of the transferred sternal pectoralis major tendon.

Fig. 7 The levator scapula, rhomboid minor, and rhomboid major are all taken off their respective medial scapular insertions and tagged for transfer.

10-cm incision was made midway between the spinous processes and the medial border of the scapula from the superior edge to the inferior angle of the scapula (Fig. 6). The atrophied trapezius was transected with electrocautery midway through its muscle belly. Draping the arm freely allowed manipulation of the extremity, which facilitated exposure to the levator scapulae and the rhomboids major and minor. The tendons were usually taken directly off the medial scapular border or alternatively with a small piece of osteotomized bone with its tendinous insertions (Fig. 7). The supraspinatus and infraspinatus muscles were elevated from their respective fossae for at least half the width of the scapula (5–6 cm). They were not elevated beyond the neurovascular bundle to protect it. This allowed for transfer of the rhomboid minor to the supraspinatus fossa and the rhomboid major to the infraspinatus fossa. A series of drill holes were made in the supraspinatus fossa and in the infraspinatus fossa (Fig. 8). The arm was abducted to reduce the scapula while the muscles were sutured down. The second incision 3 cm in length was made over the scapular spine beginning 5 to 7 cm medial to the posterior edge of the acromion to allow for transfer of the levator scapulae (Fig. 9). The trapezius, deltoid, and supraspinatus were elevated off to allow for three drill holes into the spine of the scapula. A tunnel was made between the two incisions through the trapezius, and the levator scapulae

Fig. 6 The patient is positioned laterally, right-hand side up. The head is to the left and the feet are to the right. The primary incision for the modified Eden-Lange procedure is marked with the dotted line (arrow). It is midway between the medial border of the scapula and the spinous processes.

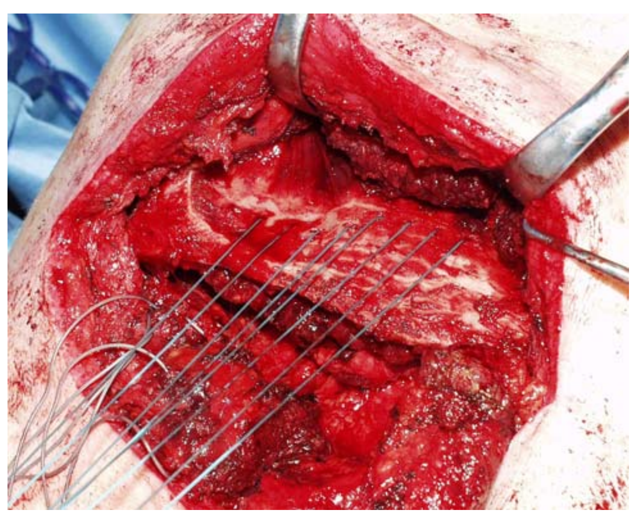

Fig. 8 A series of mattress sutures are placed in the infraspinous fossa for transfer of the rhomboid major.

Fig. 9 A second incision is made 5 to 7 cm from the posterolateral corner of the acromion along the scapular spine for subcutaneous transfer of the levator scapula.

passed through and sutured to the scapular spine. The incisions were closed in a layered fashion.

An abduction wedge was used for 4 weeks postoperatively to keep the arm in 60° to 70° of abduction. We instituted gentle passive range of motion to 140° of forward elevation and 40° of external rotation starting on postoperative day 1. At 4 weeks, the abduction wedge was removed and we began progressive strengthening. The program was aimed at dynamic scapular stabilization and used free weights, rubber sheeting, and tossing a weighted ball. Shoulder shrugs were performed with 3- to 5-pound weights and progressed to 10 pounds as tolerated. Medial retraction of the scapula was performed against resistance using rubber sheeting. These exercises actively moved the scapula to the midline. Overhead throwing of a 6-kg weighted ball helped improve scapulothoracic rhythm.

Postoperative forward elevation was recorded during routine followup visits. Patients were typically seen at approximately 2 weeks and 1, 3, 6, and 12 months postoperatively, at the very least. Postoperative visual analog score of pain and ASES evaluation questionnaires were obtained by contacting patients by telephone. Patients were also asked if they were generally satisfied with the results of the surgery and if they would undergo the surgery again. Interviews were conducted by an author not involved in care of the patients (GJG).

Results

All but two patients undergoing split pectoralis transfer had full active shoulder range of motion postoperatively (Table 1). Both of these patients had substantially impaired active range of motion preoperatively. The pectoralis transfer group had improvements in mean forward elevation (158.2°–164.5°), ASES scores (53.3–63.8), and visual analog scores (5.0–2.9). All patients were satisfied with the outcome of the procedure and would have the procedure again.

The mean ASES scores were improved for the patients undergoing the Eden-Lange procedure as well (33.3–64.6). Average forward elevation improved from 141.7° preoperatively to 151.0° postoperatively. Visual analog scores improved from a mean of 7.0 preoperatively to 2.3 postoperatively. All the patients undergoing the Eden-Lange procedure were also satisfied with the procedure and would agree to have it again in the future. No patients undergoing the Eden-Lange procedure had residual winging.

There was one postoperative complication in the patient who had the combined Eden-Lange procedure and split pectoralis transfer, a superficial wound infection, successfully treated with irrigation, débridement, and antibiotics. Another patient who underwent the modified Eden-Lange procedure had a superficial wound infection, which was also treated with no compromise of the transfer. One patient from the pectoralis transfer group was noted to have apparent loosening of the transfer 6 months postoperatively after a second trauma. She subsequently underwent scapulothoracic arthrodesis and was satisfied with her outcome. None of the remaining patients undergoing split pectoralis transfer had residual winging.

Discussion

Dynamic procedures for restoration of shoulder function after chronic scapular winging from nerve palsy in younger, active people are currently the standard of care. We describe our preferred methods of treating trapezius and serratus anterior palsy, the modified Eden-Lange procedure and the split pectoralis major transfer without fascial graft, respectively. We then asked whether these two procedures effectively treated winging and restored function. Other aims were to identify common causes of trapezius or serratus anterior palsy and elucidate difficulties in obtaining the diagnosis of scapular winging and wanted to categorize complications associated with these two tendon transfer procedures.

The major limitation of this study is it deals with a very small patient population. This is a function of the fact that scapular winging is a rare condition that is underdiagnosed. As a result, it was organized as a retrospective case series. Seven patients did not complete preoperative ASES questionnaires and five did not complete postoperative questionnaires, and were considered lost to followup, making it inappropriate to perform a statistical analysis.

The likelihood of spinal accessory nerve recovery after blunt trauma is good, whereas recovery after palsy from surgical procedures is less than 15% [13]. Patients with neurapraxic injury can be treated nonoperatively (eg, observation, physical therapy to strengthen compensatory muscles) and followed with serial electromyography. Neurolysis, nerve repair, or nerve graft is generally considered in injuries caused by surgery or penetrating trauma, preferably within 6 to 12 months of the injury [26, 36]. One patient in the Eden-Lange group had undergone unsuccessful spinal accessory nerve graft. Nonoperative treatment has also been advocated in older people who are sedentary, have minimal symptoms, or can modify their daily activities. Rehabilitation as treatment (such as strengthening accessory muscles, antiinflammatories, acupuncture, electrical stimulation, nerve blocks, or steroid injections) for chronic trapezius palsy has had poor outcomes [2, 3]. One study reported seven of eight patients treated with nonoperative rehabilitation had an unsatisfactory result [3].

Recovery from serratus anterior palsy resulting from trauma usually takes 6 to 9 months, whereas recovery from nontraumatic causes can take up to 2 years. Approximately 25% of patients with chronic serratus palsy will not respond to nonoperative treatment consisting of periscapular strengthening, range of motion, and bracing [30]. There are reports of good recovery with nonoperative treatment in nontraumatic palsy as well as in athletes with traumatic palsy [12, 15], although a large series with 6-year followup by Kauppila and Vastamaki reported persistent symptoms and limitations in chronic serratus anterior palsy treated nonoperatively [18]. Historically, repair, grafting, or neurolysis of the long thoracic nerve had not been attempted. None of our patients undergoing split pectoralis transfer had undergone long thoracic nerve surgery. Recently, however, there are case reports of successful transfer of the thoracodorsal or medial pectoral nerve when performed within 6 months of injury [27, 37].

The first dynamic procedure for treatment of trapezius palsy was described by Dewar and Harris [8], who transferred the levator scapulae insertion laterally and created a fascial sling between the medial border of the scapula and the vertebral spinous processes. This procedure was also fraught with failure, however, as a result of the inability of the small levator scapulae to substitute for the large trapezius muscle and stretching of the sling [2, 3]. Eden first described a procedure of laterally transferring the insertions of the rhomboids major and minor and the levator scapulae for treatment of trapezius palsy in 1924 [11]. Lange then reported success of this procedure in 1951 and 1959 [21, 22].

Our two modifications to the Eden-Lange procedure are meant to better anatomically reconstruct trapezius function; the rhomboids major and minor are separated to recreate the middle and inferior portions of the trapezius, and elevation of the supraspinatus and infraspinatus in their respective fossae to transfer the rhomboids more laterally helps approximate the insertion of the trapezius and theoretically adds a mechanical advantage. Also, transferring the rhomboid minor cephalad to the scapular spine in the supraspinatus fossa helps to stabilize the superior angle of the scapula and closes the gap between the levator scapulae (transferred to the lateral scapular spine) and the rhomboid minor (transferred to the infraspinatus fossa).

We demonstrated good improvements with respect to function, pain relief, and satisfaction in our cohort of patients undergoing the modified Eden-Lange procedure at an average followup of 4 years. Langenskiold and Ryoppy in 1973 reported favorable results of the Eden-Lange procedure in a series of three patients [23]. Bigliani et al. [2, 3]. in two separate studies demonstrated excellent or satisfactory results in the majority of patients treated with the modified Eden-Lange procedure in the short and intermediate term. Romero and Gerber [34] recently reported good outcomes and no complications with the Eden-Lange procedure at an impressive 32-year mean followup. Although the postoperative ASES scores were below normal, they did show improvement from the preoperative scores and the patients were all satisfied with their result, suggesting scapular winging is an extremely disabling condition.

The first surgical treatment for serratus anterior palsy was described by Tubby in 1904 [38], who transferred several fascicles of the sternal head of pectoralis major to the dysfunctional serratus anterior. Unfortunately, the atrophied serratus stretched with time leading to failure. Various other fascial sling grafts used to stabilize the scapula to the thorax were also unsuccessful [9, 41], Dynamic tendon transfers for serratus anterior palsy have undergone various iterations beginning with transfer of the rhomboid muscles described in 1951 [16] followed by techniques involving the pectoralis minor [5], and finally transfers of the teres major, levator scapulae, or combinations of these two muscles [40]. Transfer of the inferior one-third of the pectoralis major to the inferior angle of the scapula with a fascia lata graft extension was first described by Durman in 1945 [10] followed by subsequent description of transfer of the sternal head of the pectoralis major with a similar method by Marmor and Bechtol in 1963 [25].

Multiple case series demonstrated good outcomes with the method described by Marmor and Bechtol [7, 25, 29] and now many authors advocate sternal head of pectoralis major transfer with either fascia lata or hamstring autograft supplementation for chronic serratus palsy [20, 42]. A recent cadaveric study demonstrated the length of the sternal head of pectoralis is suitable for direct transfer to the inferior angle of the scapula [31]. Although there has been literature detailing the technique of two-incision split pectoralis major transfer without fascial graft [31, 40], this study is the first to demonstrate favorable clinical outcomes using this method. Similar to the patients undergoing the Eden-Lange procedure, ASES scores were improved but not completely normal, although all patients were satisfied. Eliminating the need for a graft eliminates the risk of graft stretching and treatment failure that befell the earlier stabilization procedures. Autograft harvest exposes the patient to a second surgical site, which has some degree of morbidity, albeit low. Allograft use is also not without concern.

Iatrogenic injury has historically been the major cause of spinal accessory nerve damage. Surgery in the posterior cervical triangle such as lymph node biopsy, benign mass excision, or radical neck dissection places the nerve at risk. Only one case of trapezius palsy in our cohort occurred secondary to radical neck dissection, which may be in part attributable to alterations in surgical techniques to preserve the spinal accessory nerve [4, 33, 35]. The spinal accessory nerve is also susceptible to injury from traumatic causes. Direct trauma from a lacrosse or hockey stick above the clavicle can injure the nerve [3]. Half of our patients with spinal accessory palsy were the result of acute trauma (football, waterskiing, and car accident) and one had a history of clavicle fracture.

The main cause of serratus anterior palsy in the current series was trauma, which is in agreement with prior literature [18]. Blunt trauma to the thorax or sudden depression of the shoulder are previously described traumatic causes of long thoracic nerve palsy [14]. Iatrogenic causes include injury during radical mastectomy, first rib resection, and transthoracic sympathectomy [18]. One of our patients with serratus palsy had undergone first rib resection, but it is unclear if this was causative because the patient began to have symptoms 12 years earlier after a skiing accident. Nontraumatic reasons include Parsonage-Turner syndrome, immunization, and viral illness [1, 28, 32]. Several of our patients acquired the palsy from idiopathic causes, which may be attributable to these causes.

We recommend evaluation of all periscapular muscles by electromyography. Abnormalities that can be associated with these neuropathies include decreased amplitude and prolonged distal latency. The importance of comprehensive electromyography is highlighted by the patient in this series who had two prior negative electromyograms and the second patient with combined nerve palsy who failed to have the spinal accessory palsy initially diagnosed. This patient with spinal accessory and long thoracic palsy benefited from a combined split pectoralis major transfer and Eden-Lange procedure. This combination palsy is not unheard of; in fact, it has been hypothesized long thoracic nerve palsy may develop as a traction injury secondary to an unsupported scapula in patients with concurrent spinal accessory nerve palsy [2]. Romero and Gerber noted

Table 3. Diagnosis before winging

Prior diagnoses	
Eden-Lange group	**Split pectoralis transfer group**
Impingement	Instability
Poland's syndrome	Thoracic outlet syndrome
Pectoralis rupture	Labral tear
	Cervical radiculopathy
	Impingement
	Poland's syndrome
	Pectoralis rupture

inferior results in patients with multiple nerve palsies [34]. Specific electromyograms also proved important in the patient with fascioscapulohumeral dystrophy because it demonstrated intact pectoralis major function such that it could be used to substitute for the serratus anterior.

A larger proportion of the patients with winging secondary to serratus anterior palsy were misdiagnosed than those with trapezius palsy (Table 3). Both of these diagnoses are rare and often present with vague symptoms. Bigliani et al. [2] previously reported 14 of 22 patients with trapezius palsy had an incorrect initial diagnosis. Improper diagnosis can not only cause a delay in treatment, but can also lead to unnecessary and sometimes extremely invasive surgeries. In some cases, the alternative diagnoses such as impingement syndrome and adhesive capsulitis may have been the result of shoulder girdle instability. Of note, one patient with serratus anterior palsy had undergone cervical discectomy and a recent case series identified C7 cervical radiculopathy as a possible cause for serratus anterior palsy [24].

The two minor complications in our patients were superficial wound infections likely related to draining seromas. We believe layered closure and use of a drain help decrease dead space and remove any residual fluid. A recent study detailing a technique for the Eden-Lange procedure suggested using two suction drains [36]. The patient who had a combined Eden-Lange procedure and split pectoralis major transfer may have been at higher risk to develop a seroma because multiple surgical planes were developed during the same operation. Also of note, one of the female patients undergoing split pectoralis transfer is considering cosmetic breast surgery as a result of breast contour asymmetry. This demonstrates even in patients in whom a split pectoralis transfer (as opposed to complete pectoralis transfer) is performed, there may be cosmetic breast asymmetry.

Split pectoralis transfer and the modified Eden-Lange procedure are effective methods of treating serratus anterior and trapezius palsy, respectively, in carefully selected patients who have had unsuccessful nonoperative treatment. However, we believe nonoperative treatment should be attempted in situations in which either operation might be considered, and neurolysis, nerve graft, or repair may be attempted to the spinal accessory nerve if performed within 6 to 12 months. Older patients, more sedentary patients, and patients with minimal symptoms may be better served by nonoperative treatment. Scapulothoracic fusion is still appropriate as a salvage procedure as demonstrated by its good outcome in a patient who had failed split pectoralis transfer.

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